COMPATIBILIZER FOR CRUMB RUBBER MODIFIED ASPHALT

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INTRODUCTION: The United States of America discards more than 300 million tires each year, and out of that,a large fraction of the tires is dumped into stock piles. This large quantity of tires creates an environmental problem. The use of scrap tires is limited. There is a usage potential in such fields as fuel for combustion and Crumb Rubber-Modified Asphalt binder (CRMA)[1].

The use of crumb rubber in modifying asphalt is not a new technique; it is been used since early 1960 by pavement engineers[2].

Crumb rubber is a composite of different blends of natural and synthetic rubber (natural rubber, processing oils, polybutadiene, polystyrene butadiene, and filler)[3].

Prior research had concluded that the performance of crumb rubber modified asphalt is asphalt dependent. In some cases it improves the rheological properties and in some cases it degrades the properties of modified asphalt[4].

Typical problems encountered in crumb rubber modified asphalt pavement include: raveling of pavement, poor mixing, and inconsistent application in the field.

The major objectives of this research were to achieve proper dispersion of crumb rubber particulates into asphalt and to make crumb rubber compatible modified asphalt with improvement both in high and low temperature properties, which can lead to reduced cracking, rutting, and raveling tendencies of the CRMA pavement. The approach of this study was to join the crumb rubber and asphalt molecules with small bifunctional molecules called compatibilizers.

MATERIALS AND METHODS:

Materials used: Three SHRP core asphalts, a California Coast (AAD-1), a lime treated California Valley (AAG-1), and a solvent treated West Texas intermediate (AAM-1) asphalt, were used in this study. They are representative of many of the asphalts used in the United States. These asphalts cover extended ranges of compositional characteristics such as oxygen concentration, nitrogen concentration, carboxylic acid concentration, amine concentration, asphaltene level, polar aromatic concentration, and others. All of the reagents used were analytical grade from Baxter Scientific Products, McGraw Park, IL, unless otherwise specified. The compatibilizers (polyfunctional epoxides with ethylenic and acrylic backbones) used in this study were made by the DuPont Corporation & Elf Atochem respectively. Crumb rubber (-80 mesh) was supplied by Rouse Rubber Industries Inc.

EXPERIMENTAL METHOD: The crumb rubber compatible asphalt was prepared from 400 g asphalt heated at 163^{0}C in a 600 ml beaker, followed by the addition of the compatibilizer having the epoxy ring with a glycidyl back bone (0.006-0.023 milimoles compatibilizer per g asphalt) to the asphalt with continuous stirring for 15-20 minutes. The crumb rubber (6-15%) was then dispersed into the hot asphalt compatibilizer mixture with continuous stirring and heating for 3 hours.

TEST METHODS: 1. The American Association of State Highway and Transportation Officials (AASHTO) Standard Method, No. PP5-93, was used for the separation test.

2. The AASHTO Standard Test Method, No. TP1-93, was used for determining the flexural creep stiffness of the asphalt binder

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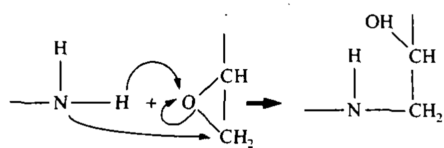
using the Bending Beam Rheometer (BBR).
3. The AASHTO Standard Test Method, No. TP5-93, was used for determining the rheological properties of asphalt binder using a Dynamic Shear Rheometer (DSR).

<u>Rheological Characterization:</u>

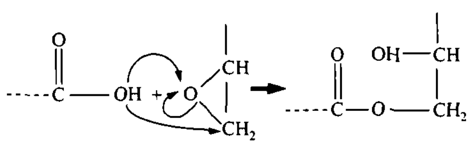
High temperature behavior by DSR: A Dynamic Shear Rheometer (Rheometrics DSR II) was used to determine the high temperature rheological properties of the virgin, control, and compatible modified binders by using parallel plate geometry. A time sequence (3 minutes) at three temperatures from 52-76°C, with a torque of 20.66 g.cm at a frequency of 10 rad/s was used. The rheological behavior of the binders was calculated by $G^*/\sin\delta$.

Low Temperature Behavior by BBR: A Cannon Bending Beam Rheometer (BBR) was used to determine the low temperature rheological properties of the virgin, control, and compatible modified binders. Samples were run in triplicate at -24, -18, and -12°C to measure the creep stiffness (S value) and the change of stiffness with time (m value).

RESULTS & DISCUSSION: The possible reaction between the asphalt functional groups (carboxylic or amino) and the epoxy groups of the compatibilizer is as follows:



Proposed reaction mechanism between the amine and epoxy groups[5]



Proposed reaction mechanism between the carboxylic and epoxy groups[5]

This type of mechanism is already reported in literature[5]. In this mechanism, the hydrogen atom of the secondary amine or carboxylic group can open the epoxy ring very easily and bring about the bonding. Physically, formation of clumps was not observed occurring in the compatible modified binder reaction, as it was in the control, an indication of proper dispersion of the crumb rubber into asphalt.

<u>RHEOLOGICAL PROPERTIES:</u>

Rheological properties of the asphalts used (AAD-1, AAG-1, & AAM-1), the control (asphalt mixed with crumb rubber (CRM)under the same reaction conditions), and the crumb rubber compatible modified asphalt are illustrated in figures I through VI. Figures I and II show continuous SHRP performance grading (PG grading) of AAD-1; the virgin asphalt passes the criteria for stiffness at 63°C, the control and modified binder pass at 80°C. Figure I also shows the low temperature rheological data for the virgin, control, and modified binders; the virgin passes the SHRP performance specification at -31°C, the control passes at -28°C, and the modified binder passes at -35°C. Asphalt AAD-1 shows high temperature improvement as compared to the virgin on addition with the CRM (control). The same observation was observed with the modification. However, the low temperature shows a different behavior; the control was degraded as compared to the virgin, but the modified binder shows significant improvement, i.e. by 7°C (more than one PG grading interval). Thus, the addition of crumb rubber to asphalt does not always improve the low temperature properties; asphalt AAD-1 is a case in point. The addition of crumb rubber to asphalt is asphalt dependent. Figure II shows the useful temperature range (the sum of the high and low temperature PG grades) for the virgin, control, and the modified binder of AAD-1. The virgin asphalt shows 94°C as the useful temperature range; whereas, the control and modified binder shows 108°C and

115^{0}C. The product from the addition of crumb rubber and a compatibilizer to asphalt is improved by 2.3 and 3.5 PG-grading intervals (6°C), which, in this economically driven era, is very significant from the refinery point of view. The use of crumb rubber in asphalt is also advantageous in that CRM contains UV resistant additives.

Figure III indicates the rheological properties (continuous PG grading) of asphalt AAG-1, its control, and its modified compatible binder. The addition of crumb rubber to this Californian asphalt shows simultaneous improvement of low and high temperature properties, i.e. from PG 62-19 to PG 66-24. The modified compatible binder shows further improvement for both high and low temperature rheological properties, i.e. PG 72-29. The asphalt, AAG-1, shows low temperature rheological properties that are different from those of asphalt AAD-1. Figure IV shows the useful temperature range for asphalt AAG-1, its control, and its compatible modified binder. The virgin asphalt in this case has a useful temperature range of 81^{0}C, whereas, its control and the modified compatible binder have useful temperature ranges of 90 and 101^{0}C respectively. In this case the addition of crumb rubber and its compatible product shows an increase of 1.5 and 3.3 PG-grading intervals. This is very significant as compared to the virgin material.

Figure V shows the rheological properties of the virgin, control, and modified compatible binder asphalt AAM-1 (Californian valley solvent treated asphalt). The continuous PG-grading for the virgin binder shows PG 66-23^{0}C; whereas, its corresponding control and compatible modified binder shows PG 68-30 and PG 73-32 respectively. The improvement in the PG grading of this asphalt is not as significant as it was for the other two asphalts, but it is still significant. Figure VI shows the useful temperature ranges for the virgin, its control, and its compatible modified binder, as 89, 101, and 105^{0}C respectively. Therefore the addition of crumb rubber shows improvement by 2 and 2.7 PG-grading intervals as compared with the control and the compatible modified binder respectively.

From the above discussion it is clear that the compatible modified binder rheologically performs better than its control or its virgin binder. The process to prepare crumb rubber modified compatible asphalt may be accomplished with some degree of success. In this study the compatible modified binder was not only properly dispersed but reproducible results were also obtained.

CONCLUSION: The use of a compatibilizer can 1)enhance the solubility of crumb rubber into asphalt and 2)improve the rheological properties of crumb rubber modified asphalt. Modified compatible asphalt is advantageous over the virgin and its control by having a wider useful temperature range. The use of modified compatible asphalt has the potential to prevent asphaltic pavement from raveling and may increase the use of scrap tires. The amount of compatibilizer used in asphalt is dependent on the source of asphalt.

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Figure I

Continuous Rheological Grading of Asphalt AAD -1 (Glycidyl)

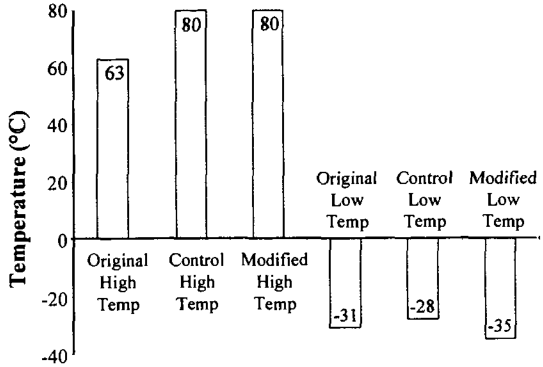

Figure II

Useful Temperature Range for Asphalt AAD-1, Control, and Compatible Modified Binder

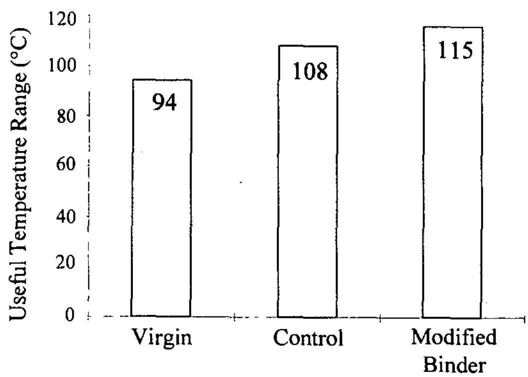

Figure III

Continuous Rheological Grading of Asphalt AAG -1 (Glycidyl)

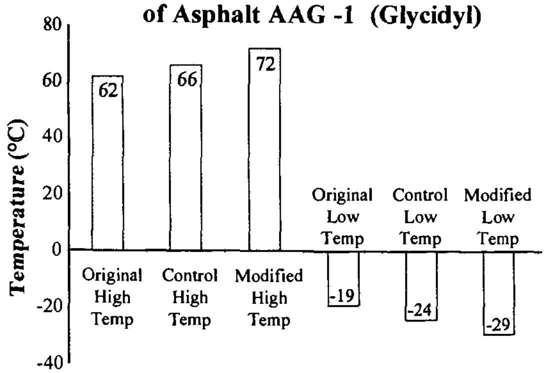

Figure IV

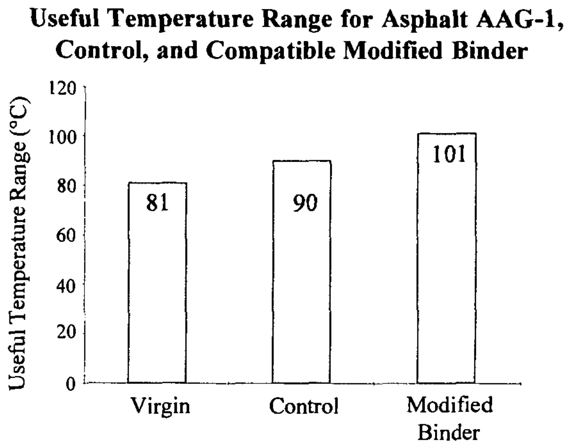

Figure V

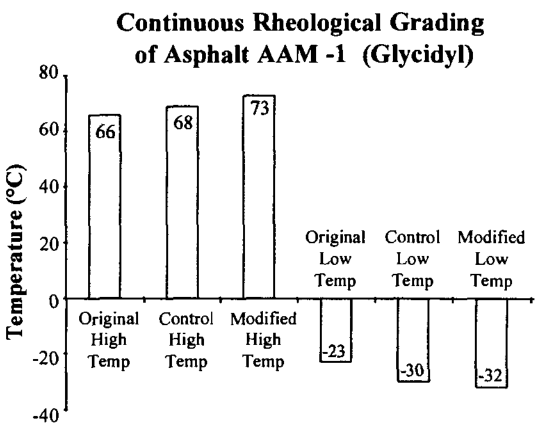

Figure VI